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18

DISTRIBUTION OF SHORT PERIOD P-PHASE AMPLITUDES OVER LASA

9 JUNE 1967

Prepared For

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D. C.

By

F. A. Klappenberger

TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office
ARPA Order No. 624

DISTRIBUTION OF SHORT PERIOD

P-PHASE AMPLITUDES OVER LASA

9 June 1967

SEISMIC DATA LABORATORY REPORT NO. 187

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Project Title:	Seismic Data Laboratory
ARPA Order No.:	624
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Name of Contractor:	TELEDYNE, INC.
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Project Manager:	William C. Dean (703) 836-7644

P. O. Box 334, Alexandria, Virginia

AVAILABILITY

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TABLE OF CONTENTS

ABSTRACT

The behavior of short period p-phase amplitudes over LASA has been investigated for several earthquakes. It has been found that the distribution of the peak-to-peak amplitudes across a subarray approaches a log-normal distribution for those events studied.

1. INTRODUCTION

In the following, we will consider the distribution of the peak to peak (p-p) amplitudes for several events at LASA and show that this data approaches a log-normal distribution.

2. PROCEDURE

Plotting the p-p amplitudes of all SPZ seismometers at LASA for a single event against frequency of occurance yields a graph which seems to have no familiar probability distribution. Figure 1, which shows the p-p amplitudes of an earthquake originating in N. Columbia is a typical graph of this type. However, if we inspect the p-p amplitudes that are associated with a given subarray, a pattern emerges. There is generally a modal clustering with a short tail toward decreasing values and a long tail toward increasing values suggesting that the data may come from a log-normal distribution (cf. Fig. 2). For this data, tests of log-normality of the population were performed by making graphs of several subarrays on log-normal probability paper (cf. Figs. 3-13). These graphs show that the data approximates a straight line rather well, and hence we conclude at least that the log-normality of the population should not be rejected, and hence subject to further evidence, we tentatively accept the hypothesis.

The validity of this hypothesis can be checked empirically by gathering considerably more data than is available from an individual subarray. Combining data recorded by all subarrays for several events will provide sufficient data for this purpose, however, a minor detour which we shall next discuss must be made before incorporating the data from different subarrays and different events into the same distribution study.

By observing Figures 14 through 21, it is clear that some subarrays exhibit a higher degree of sensitivity for events from one source region than for events from another. This characteristic is distinctly illustrated by Figure 22 which presents the consistency of order among subarray means for three closely grouped N. Columbia earthquakes and by Figure 23 which shows no similar strong ordering among more widely separated events. This phenomenon has been noted previously* and is supported by findings in other work**. In relation to this report, these consistencies indicate that the individual subarrays are biased in a certain sense due to the travel path of the source signal. Since the elements in each subarray are closely spaced, in comparison to the distance separating subarray centers, we can eliminate the individual subarray preference from all of the subarrays by considering each subarray as a sampling of the population of the p-p amplitudes and standardizing each sampling in the usual sense, i.e., if a subarray has a $N(m,s)$ distribution describing the behavior of the observations x, then by the linear transformation $y = \frac{m-x}{s}$ we have the standardized distribution $N(0,1)$. By applying this transformation to all subarrays over every event, we can pool all subarrays and all events and then investigate the properties of the entire pool. If the assumption that the logarithms of the p-p amplitudes in each subarray are normally distributed is valid, then the pooled distribution will also be normally distributed.

---

* D. E. Frankowski in a personal communication said that he has found a similar consistency for certain events from Mexico and from the Kurile Islands.

** In a separate investigation by this writer, it has been found that a high correlation exists among the subarray averages of logarithms of the p-p amplitudes recorded at LASA for events originating very close together. The groups of events in this study came from widely separated areas and hence the generality of the assumption seems reasonable.

Eight events were selected (strictly on the basis of reasonable availability) for this investigation. Out of a possible 168 (i.e., 8 x 21) seismograms available, 11 had to be eliminated because of non-functioning instruments. The remaining 157 seismograms provided 3925 (i.e., 157 x 25) usable amplitude records (25 per seismograms) for final processing.

3. RESULTS

Reading, standardizing, and sorting the p-p amplitudes was performed on the 1604-CDC. Figure 24 presents a histogram showing the standardized distribution of the 3925 logarithms of the p-p amplitudes. A normal curve has been fitted over the histogram to illustrate the tendency toward normality of the logarithmica data. Figure 25 shows the same data plotted on normal probability graph paper. These figures give a visual indication regarding the normality of the data. Statistically, the distribution was χ^2 -tested for normality with the result that at the 5% level of significance the sample distribution is consistent with the hypothesis that the parent distribution is normal.

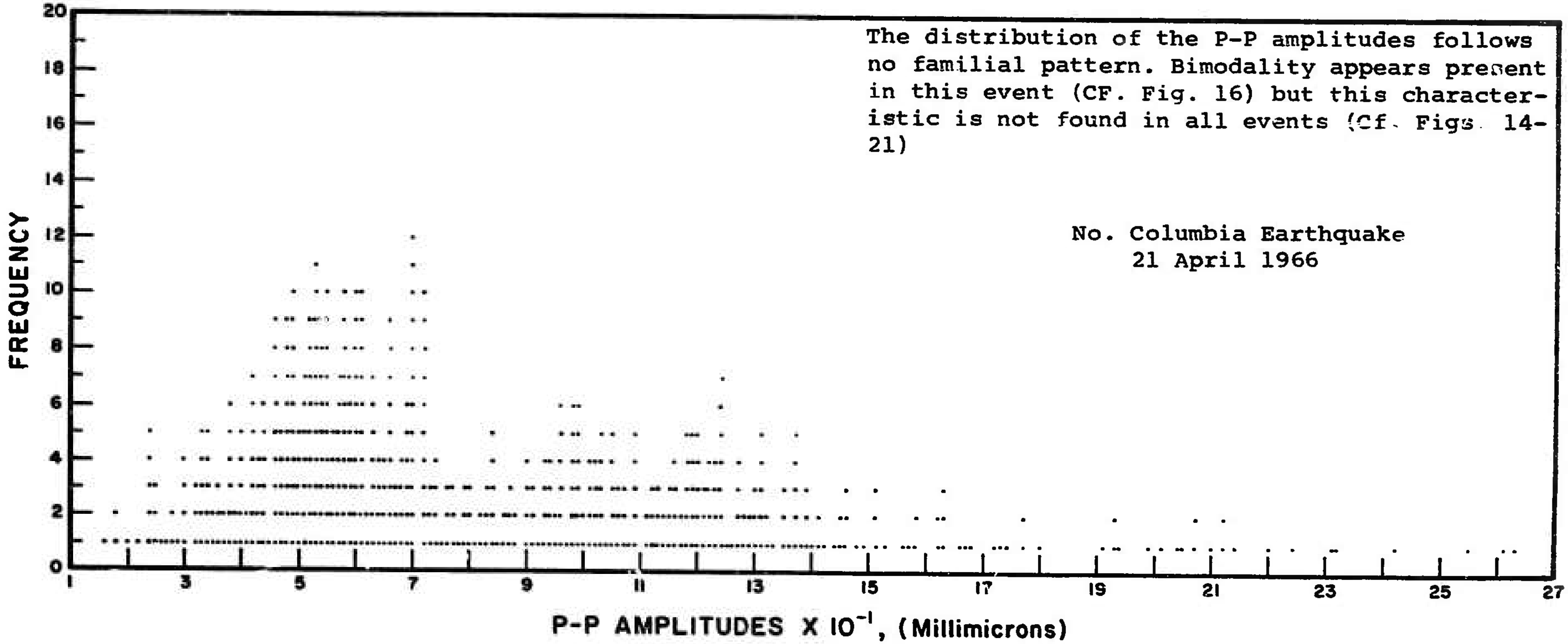

The distribution of the P-P amplitudes follows no familial pattern. Bimodality appears present in this event (CF. Fig. 16) but this characteristic is not found in all events (Cf. Figs. 14-21)
No. Columbia Earthquake
21 April 1966
FREQUENCY
0
2
4
6
8
10
12
14
16
18
20
1
3
5
7
9
11
13
15
17
19
21
23
25
27
P-P AMPLITUDES X 10^{-1}, (Millimicrons)

Figure 1

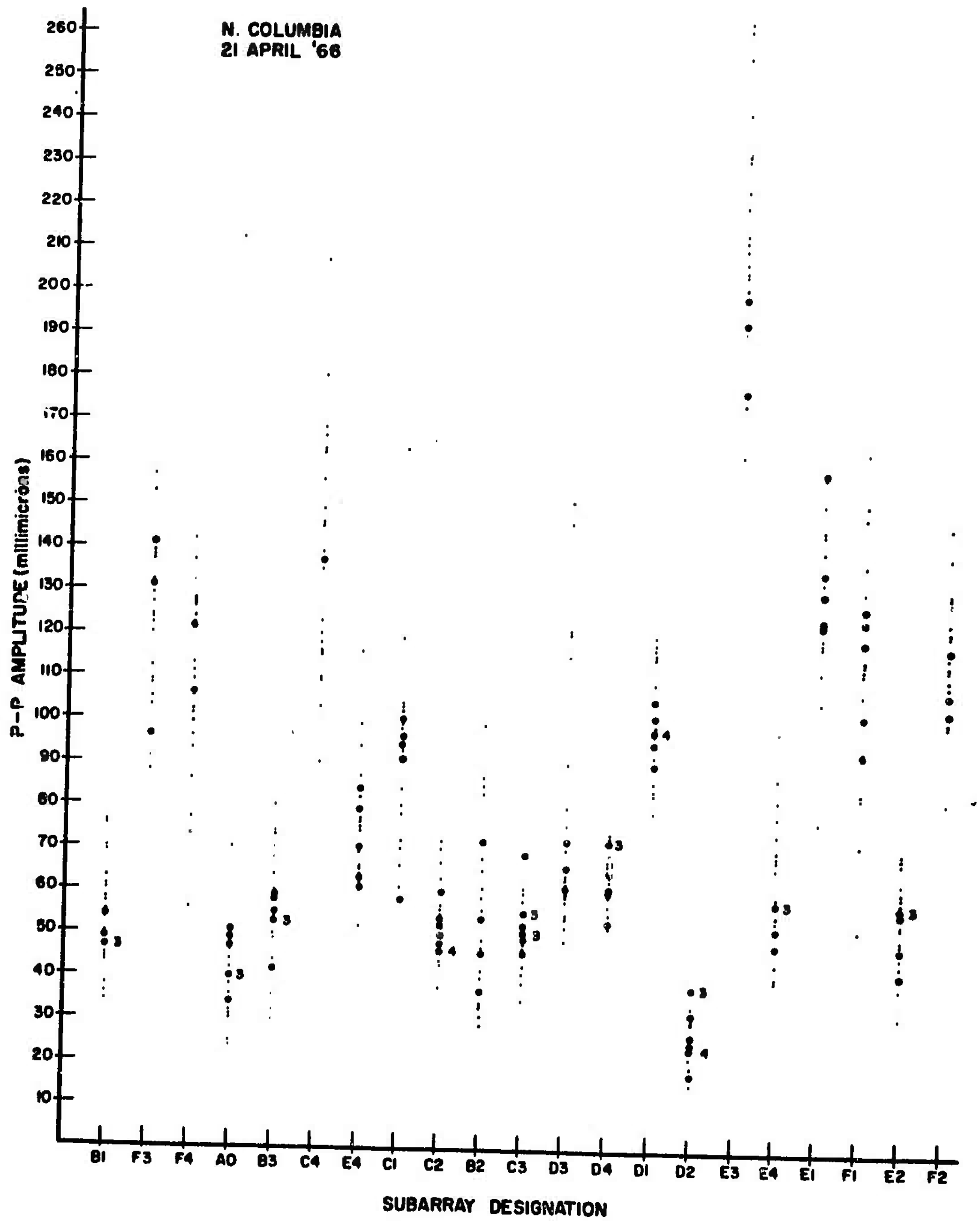

N. COLUMBIA
21 APRIL '66
P-P AMPLITUDE (millimicrons)
SUBARRAY DESIGNATION
B1 F3 F4 A0 B3 C4 E4 C1 C2 B2 C3 D3 D4 D1 D2 E3 E4 E1 F1 E2 F2

Figure 2

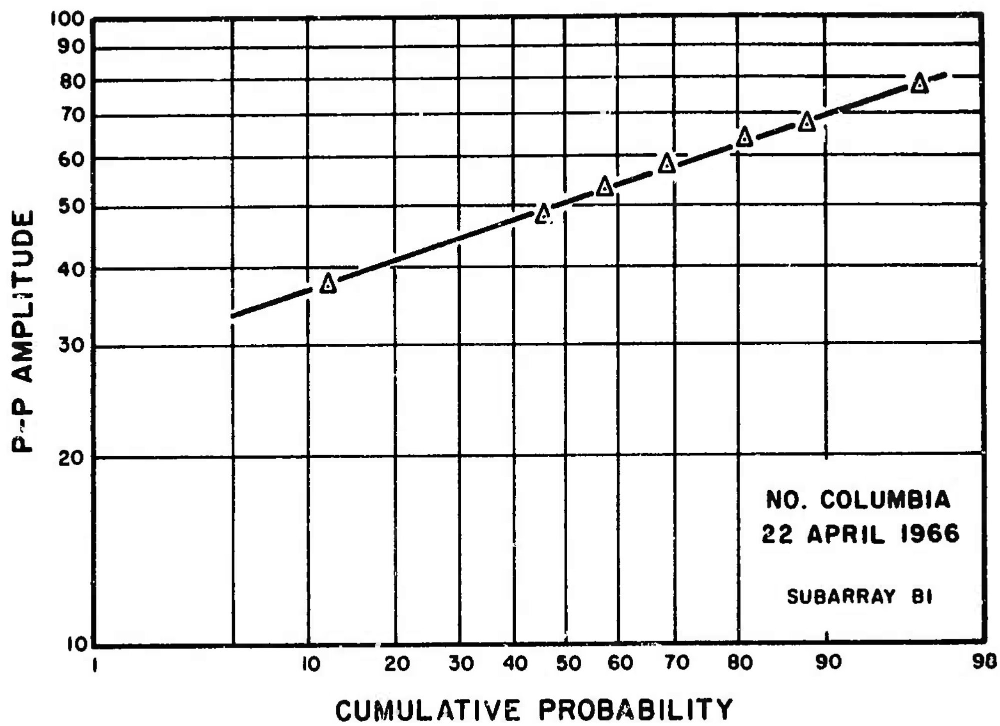


Figure 3

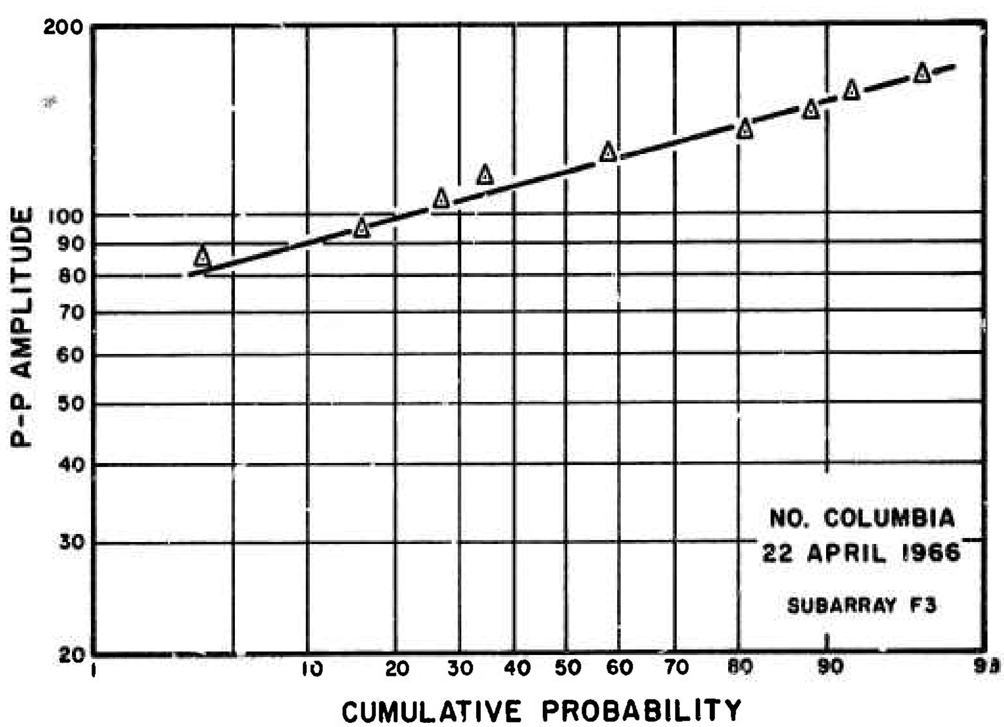


Figure 4

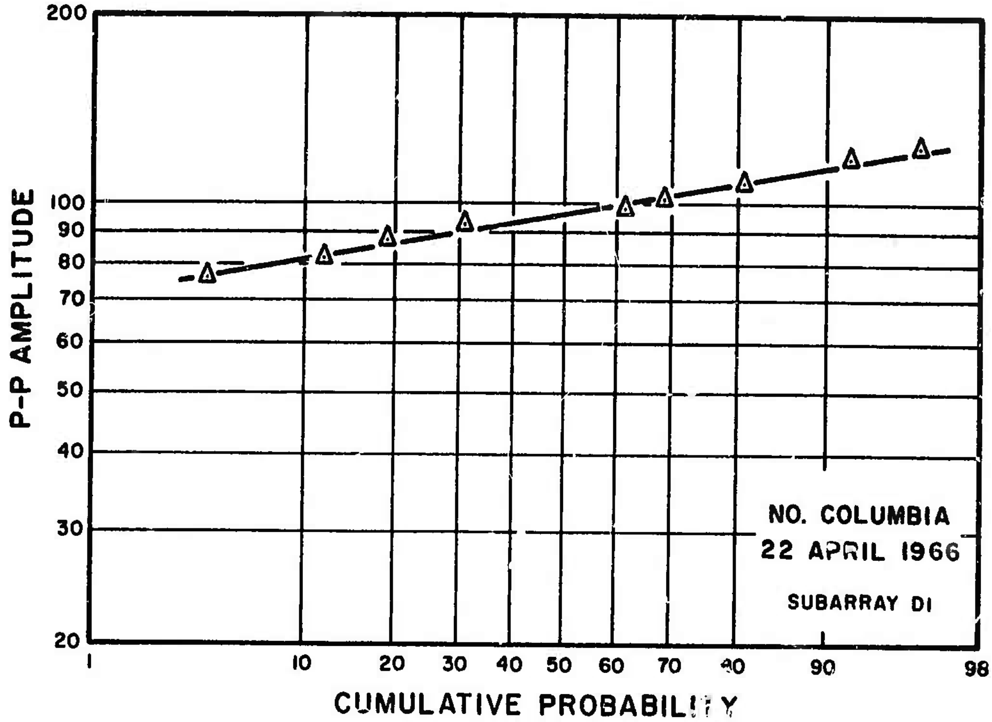


Figure 5

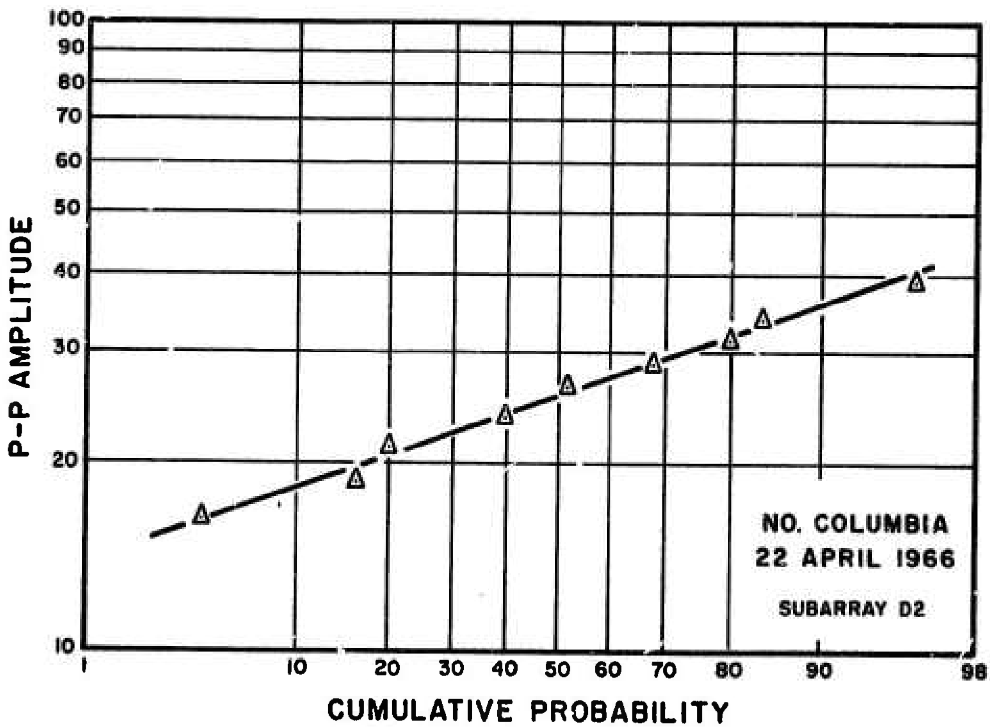


Figure 6

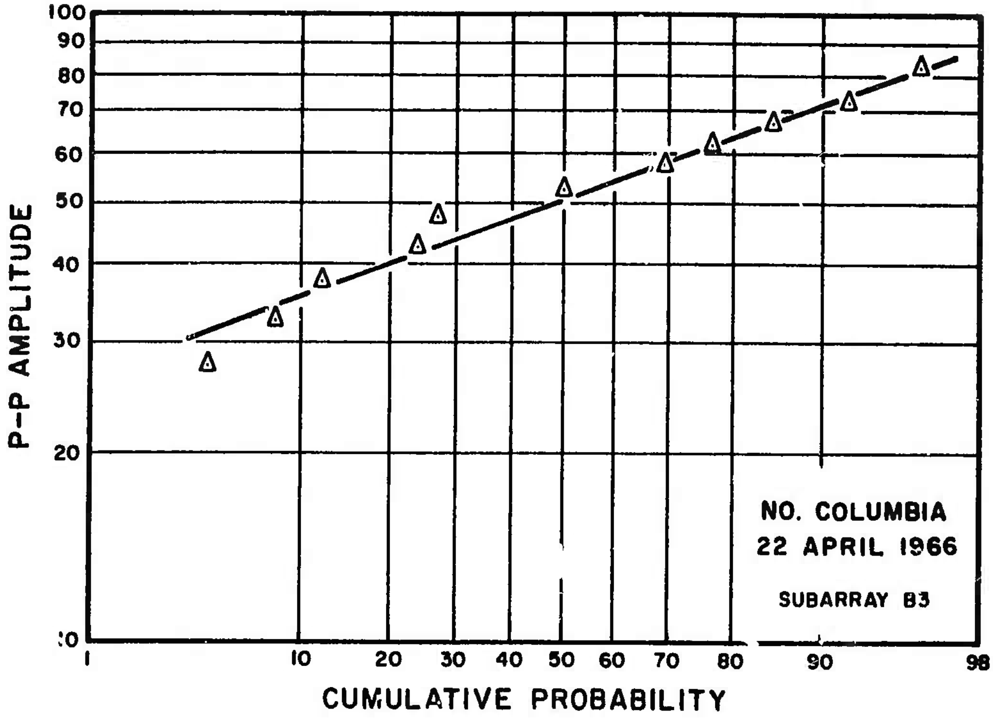


Figure 7

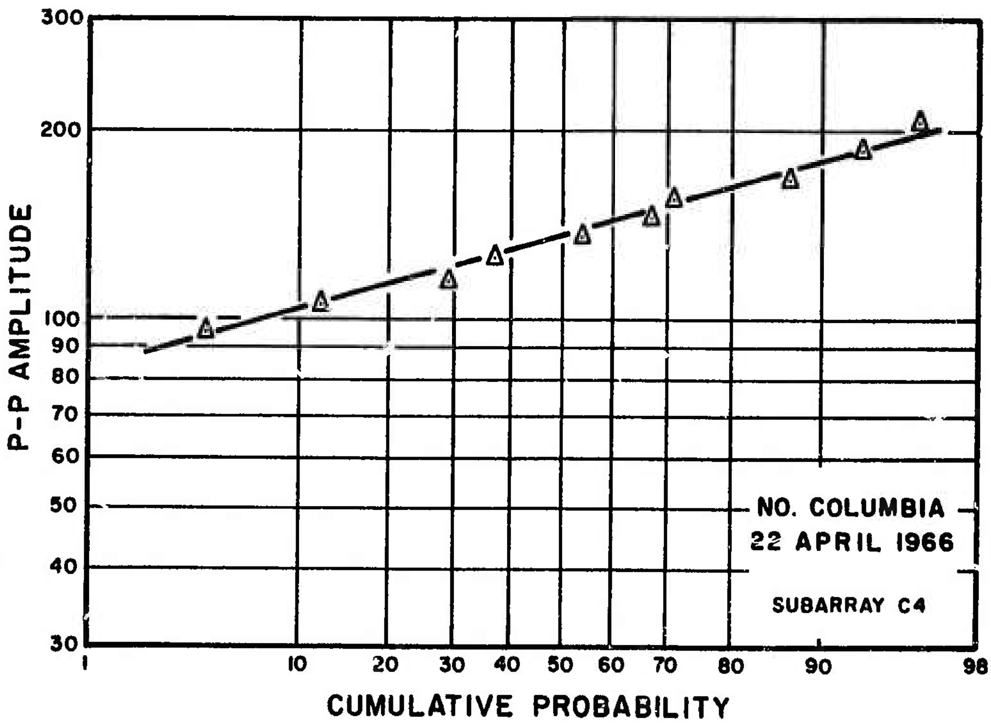


Figure 8

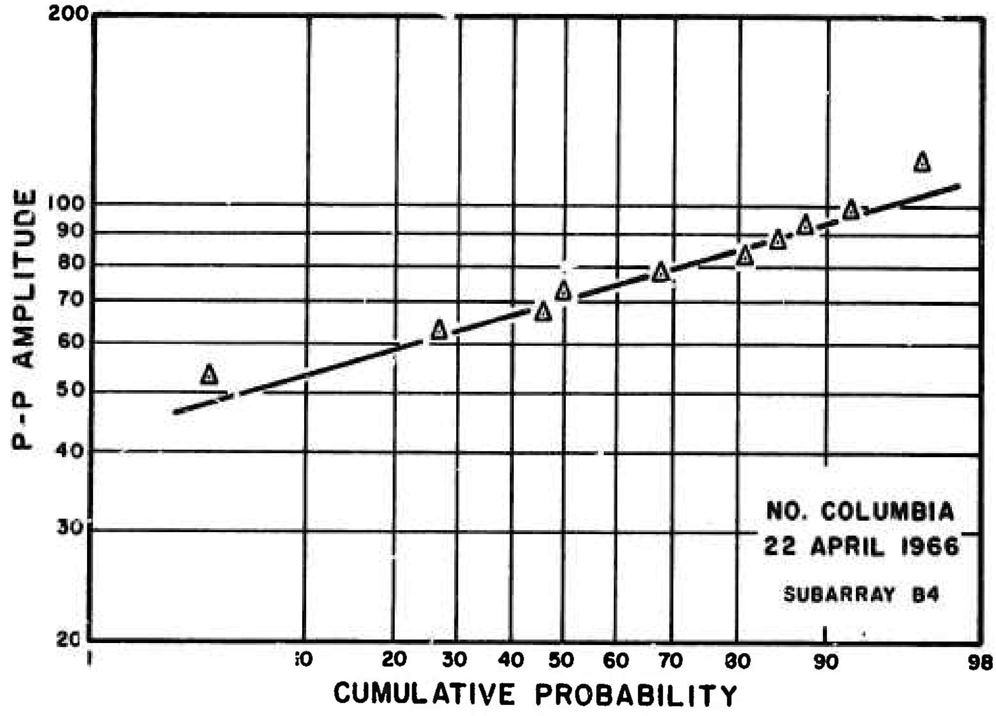


Figure 9

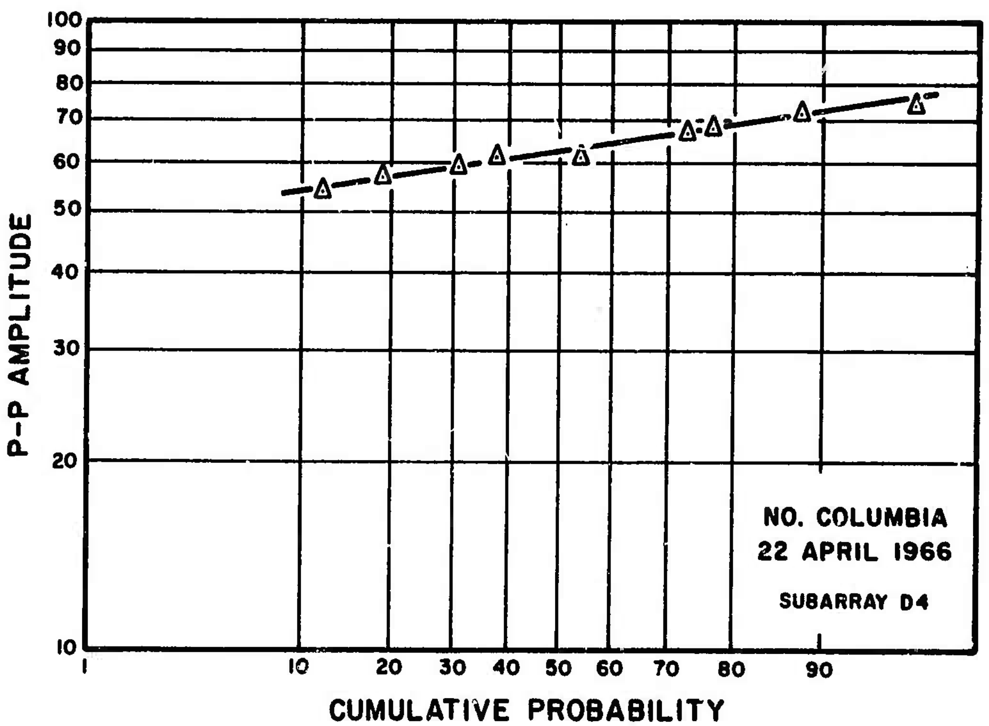


Figure 10

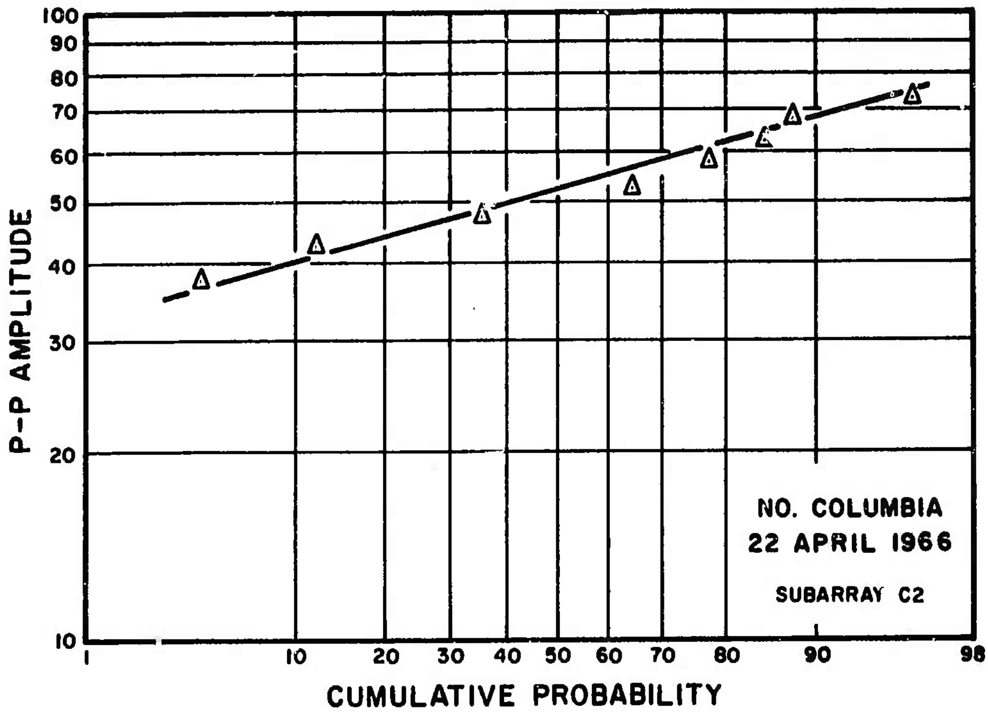


Figure 11

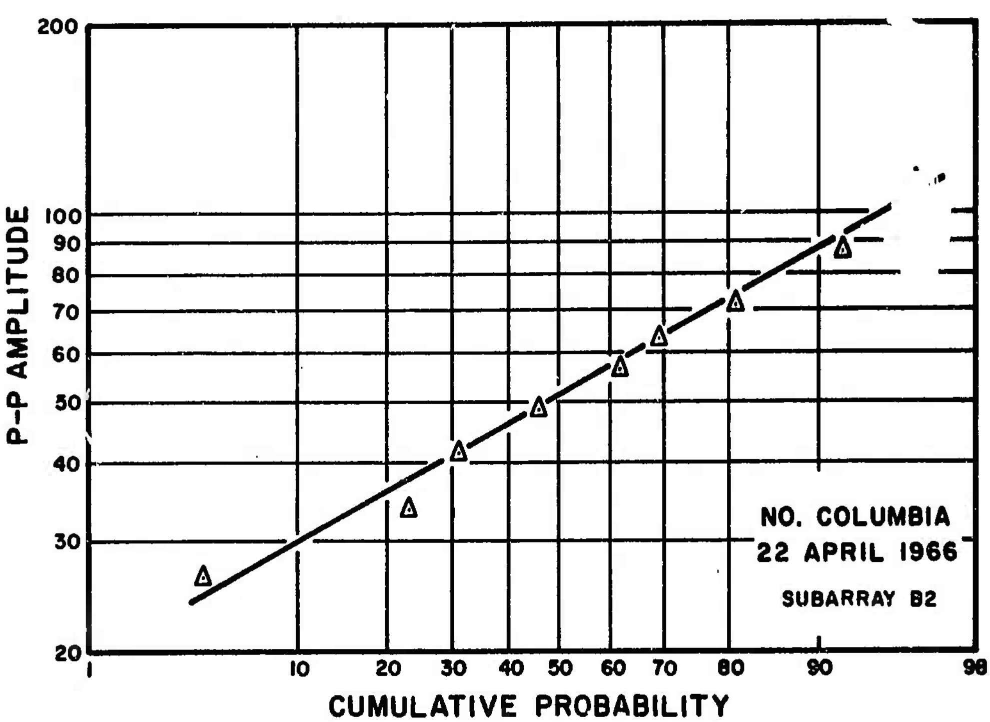


Figure 12

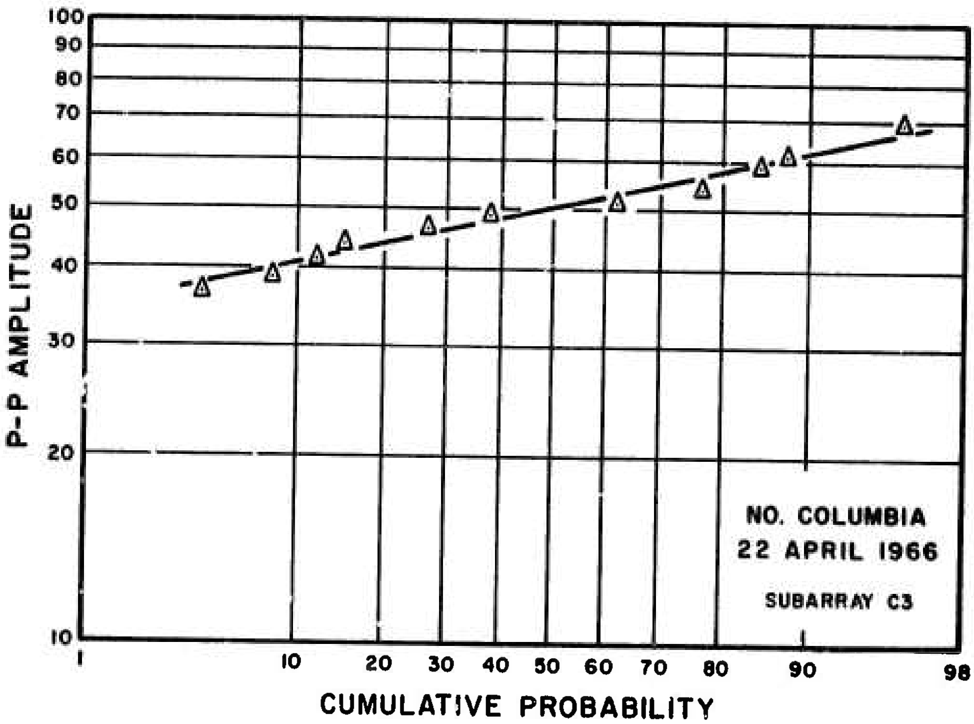

100
90
80
70
60
50
40
30
20
10
P-P AMPLITUDE
1
10
20
30
40
50
60
70
80
90
98
CUMULATIVE PROBABILITY
NO. COLUMBIA
22 APRIL 1966
SUBARRAY C3

Figure 13

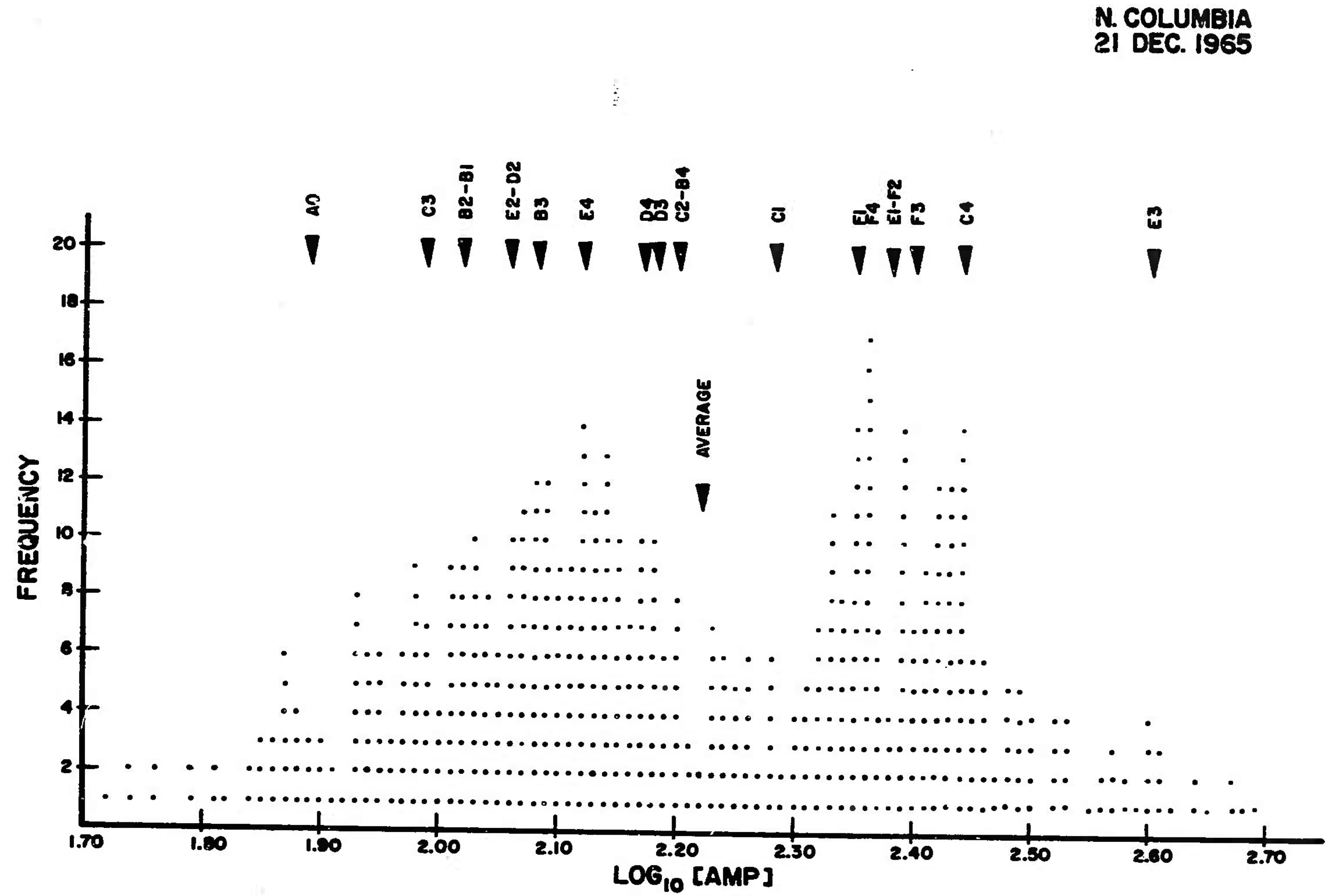

N. COLUMBIA
21 DEC. 1965
A0
C3
B2-B1
E2-D2
B3
E4
D4
D3
C2-B4
C1
E1
F4
E1-F2
F3
C4
E3
AVERAGE
FREQUENCY
20
18
16
14
12
10
8
6
4
2
1.70
1.80
1.90
2.00
2.10
2.20
2.30
2.40
2.50
2.60
2.70
LOG10 [AMP]

Figure 14

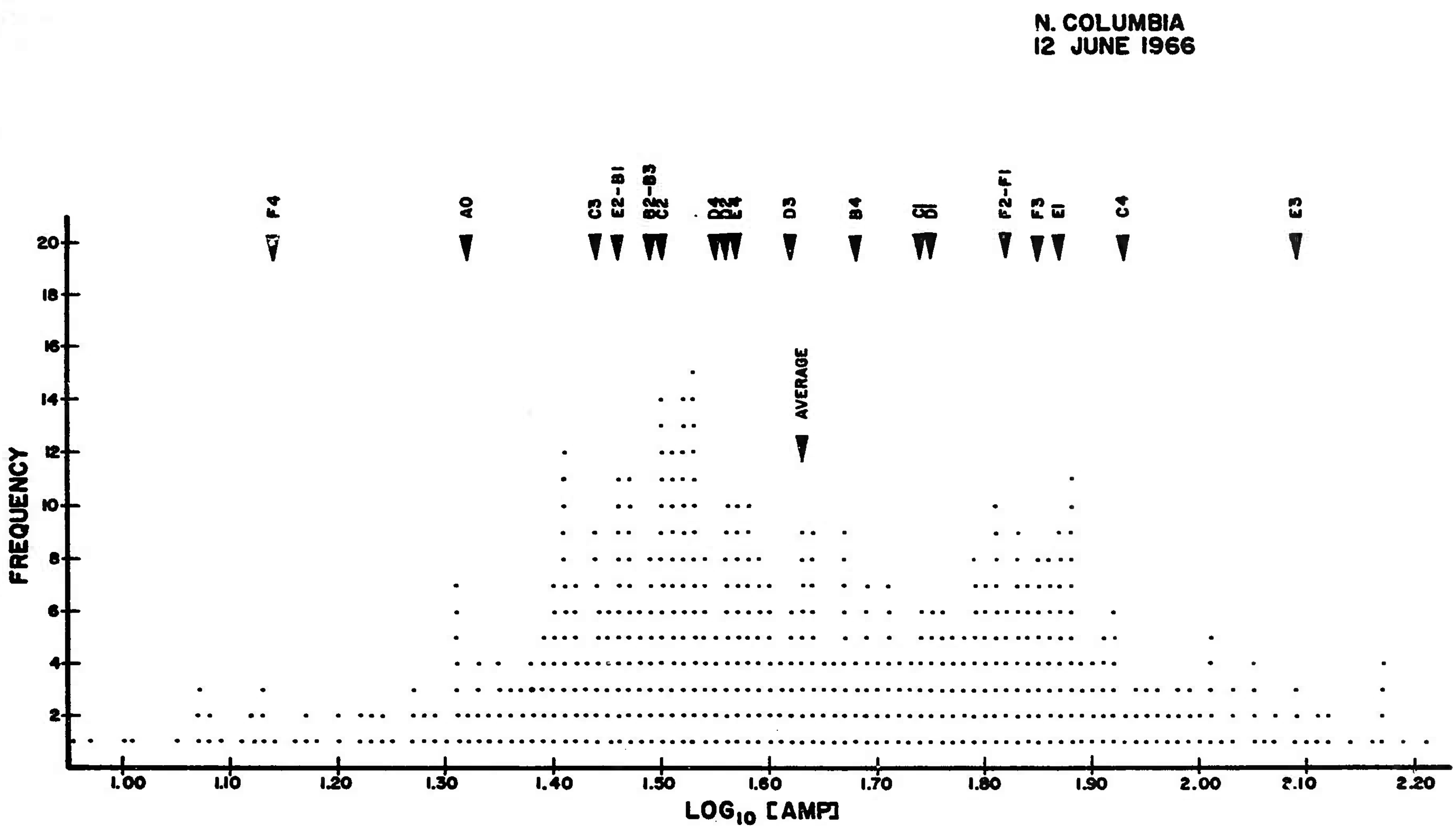

N. COLUMBIA
12 JUNE 1966
F4
A0
C3
E2-B1
B2-B3
C2
D3
B4
F2-F1
F3
E1
C4
E3
AVERAGE
FREQUENCY
20
18
16
14
12
10
8
6
4
2
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2.10
2.20
LOG10 [AMP]

Figure 15

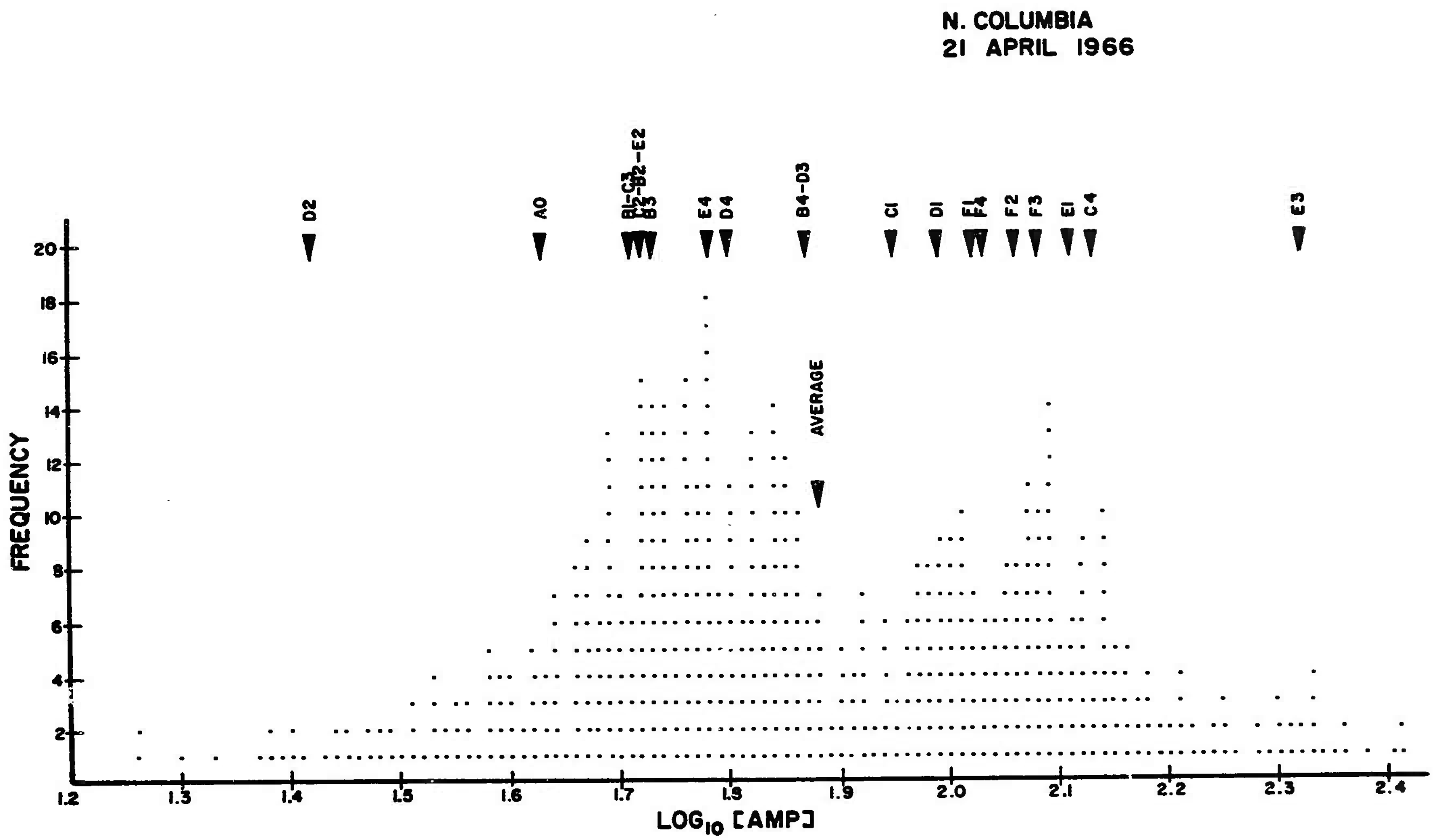

N. COLUMBIA
21 APRIL 1966
D2
A0
B1-C3
A2-B2-E2
B3
E4
D4
B4-D3
C1
D1
E1
F4
F2
F3
E1
C4
E3
AVERAGE
FREQUENCY
20
18
16
14
12
10
8
6
4
2
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
LOG_{10} [AMP]

Figure 16

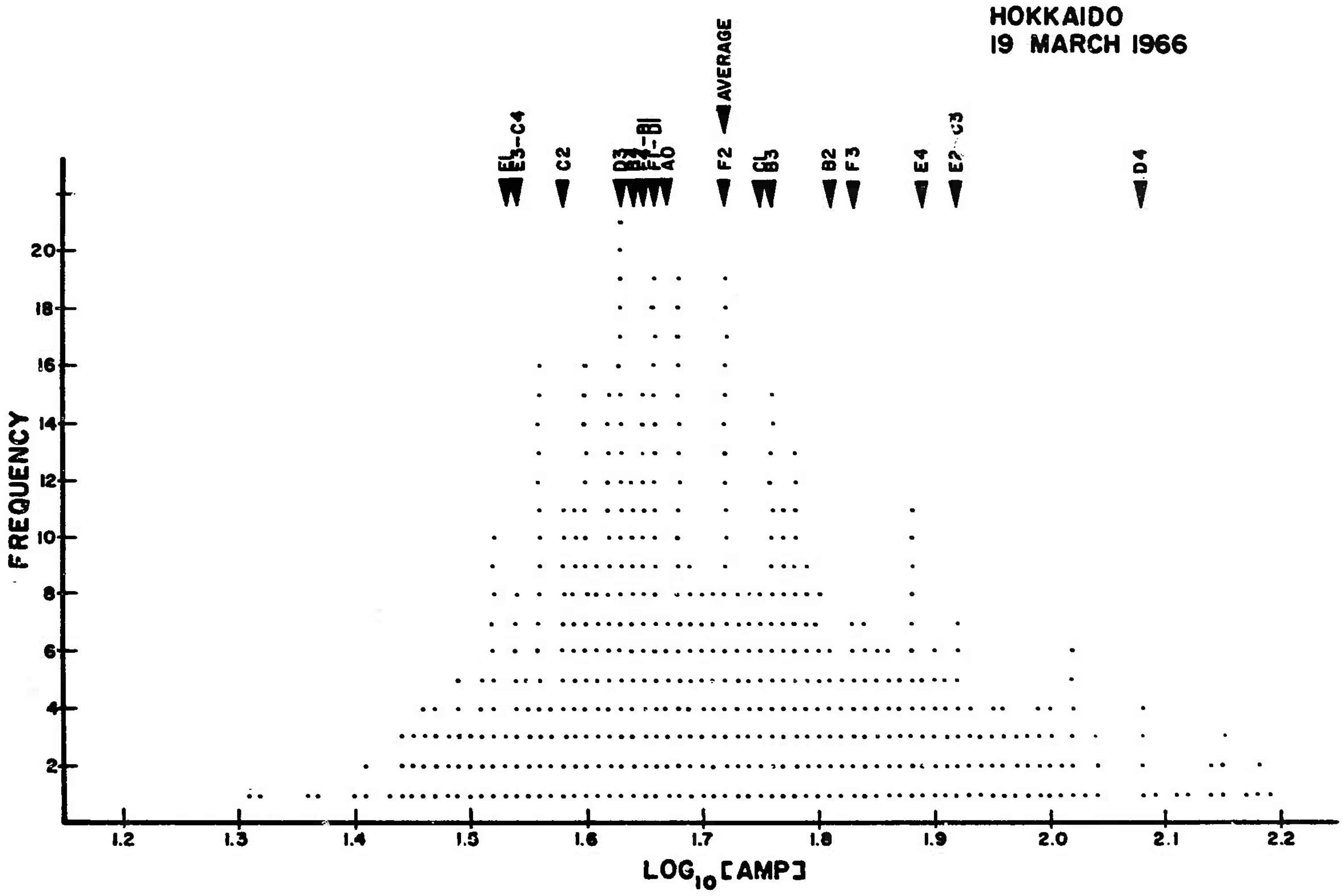

HOKKAIDO
19 MARCH 1966
AVERAGE
E1
E3-C4
C2
D3
F1-B1
A0
F2
C1
B3
B2
F3
E4
E2 C3
D4
FREQUENCY
20
18
16
14
12
10
8
6
4
2
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
LOG10 [AMP]

Figure 17

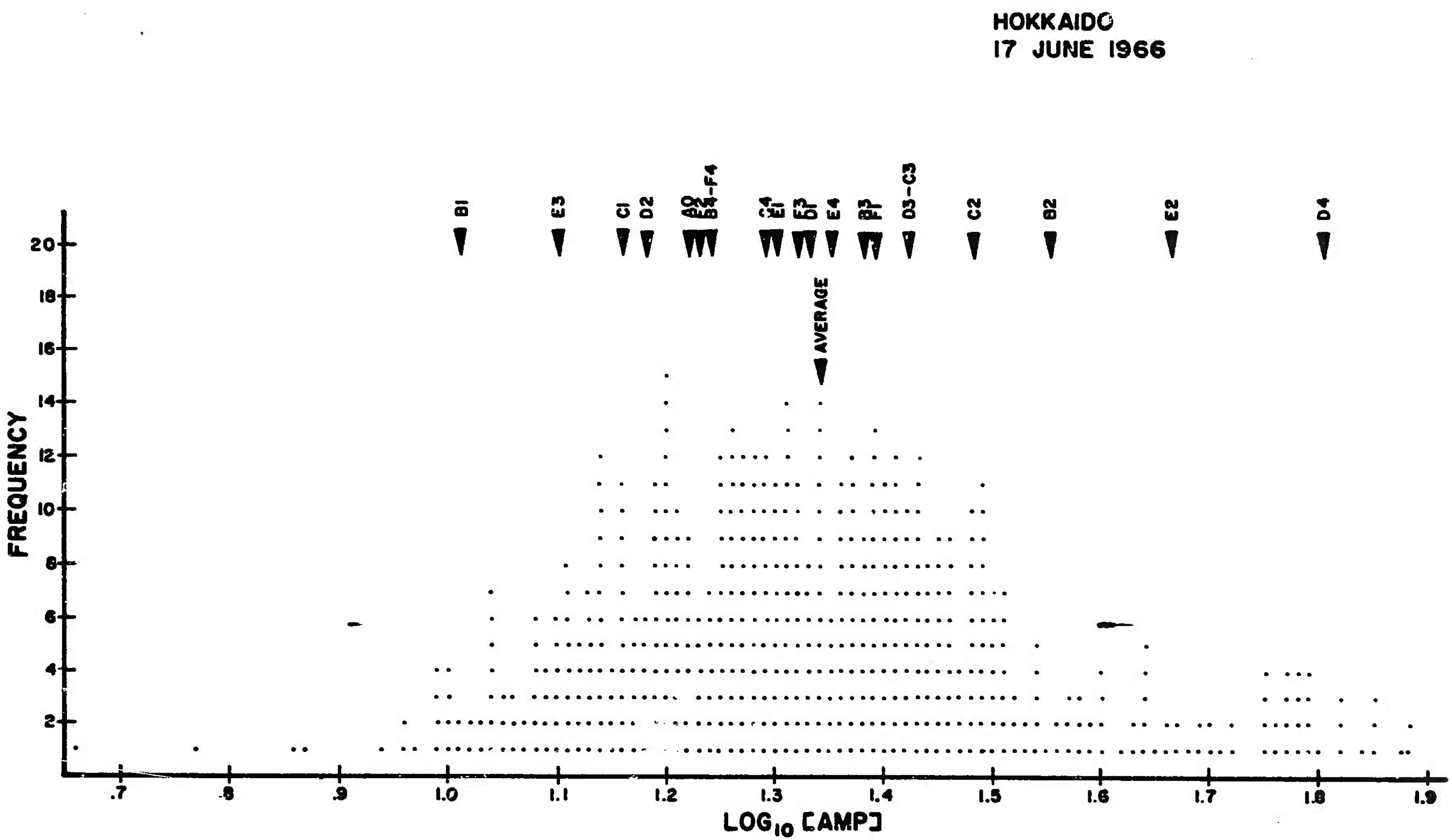

HOKKAIDO
17 JUNE 1966
FREQUENCY
LOG10 [AMP]
AVERAGE
B1
E3
C1
D2
03-C3
C2
B2
E2
D4
E4
20
18
16
14
12
10
8
6
4
2
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

Figure 18

MARIANAS
20 MAY 1966

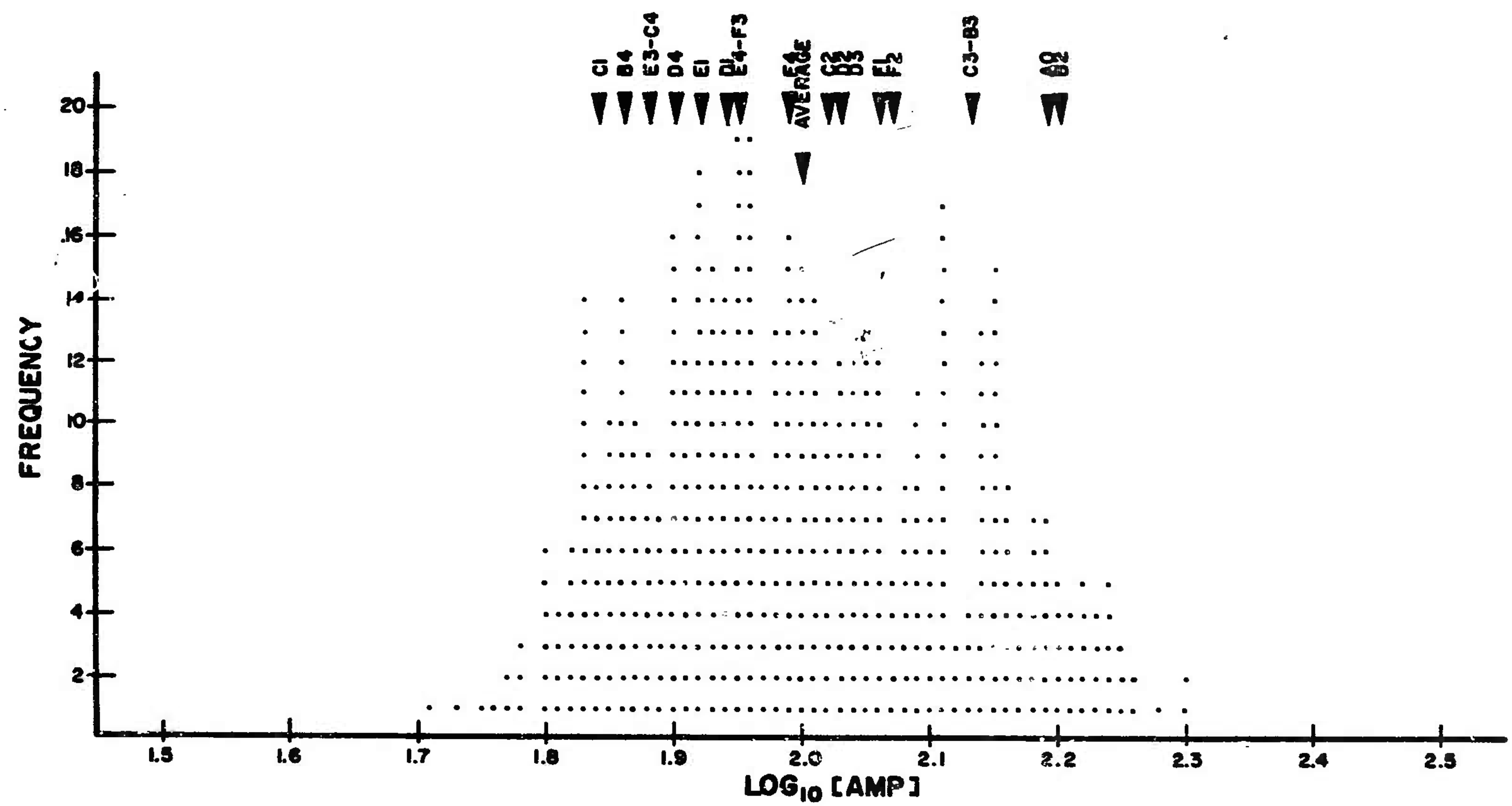
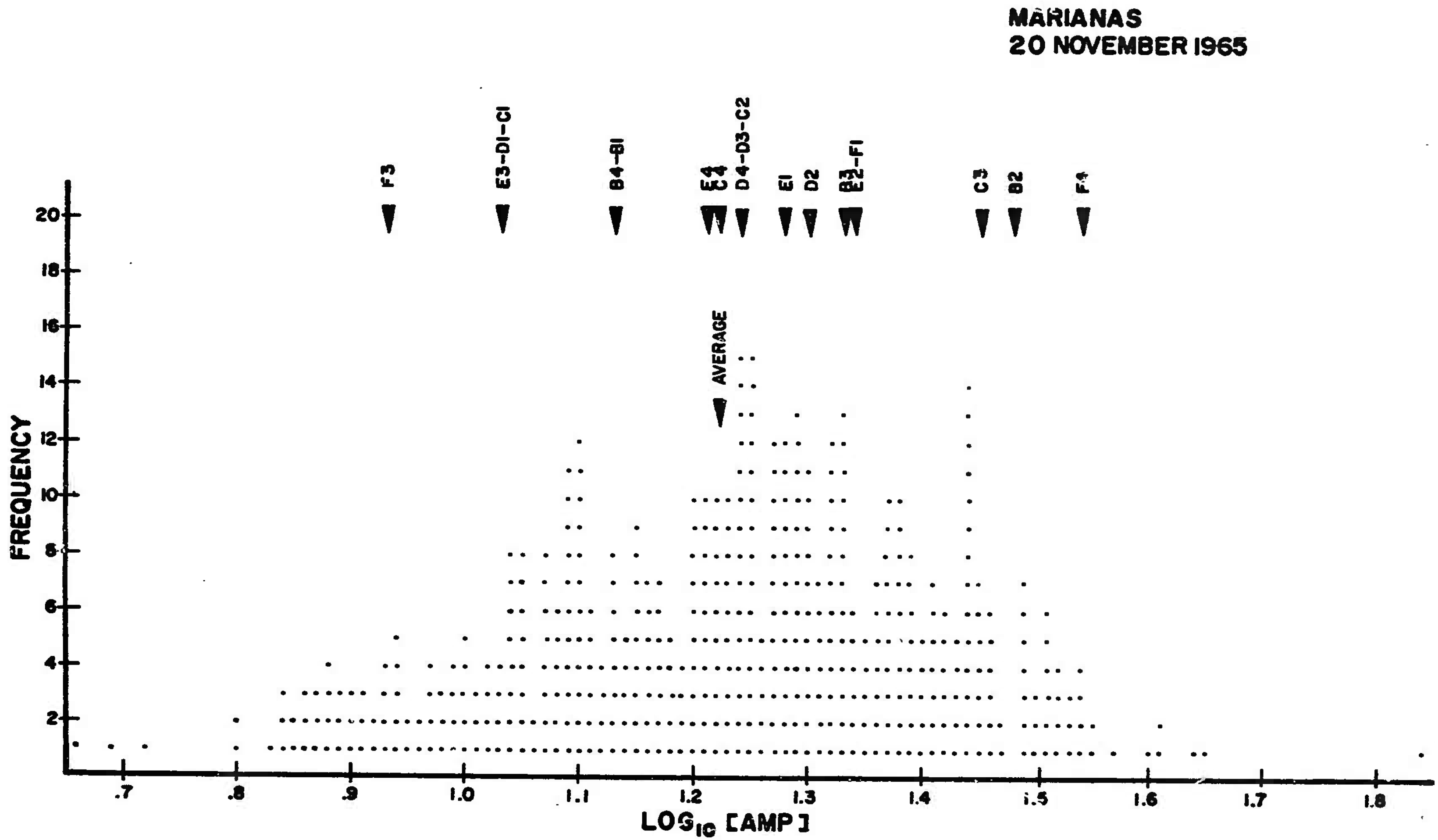


Figure 19



MARIANAS
20 NOVEMBER 1965
F3
E3-D1-C1
B4-B1
E4
C4
D4-D3-C2
E1
D2
B3
E2-F1
C3
B2
F4
AVERAGE
FREQUENCY
20
18
16
14
12
10
8
6
4
2
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
LOG10 [AMP]

Figure 20

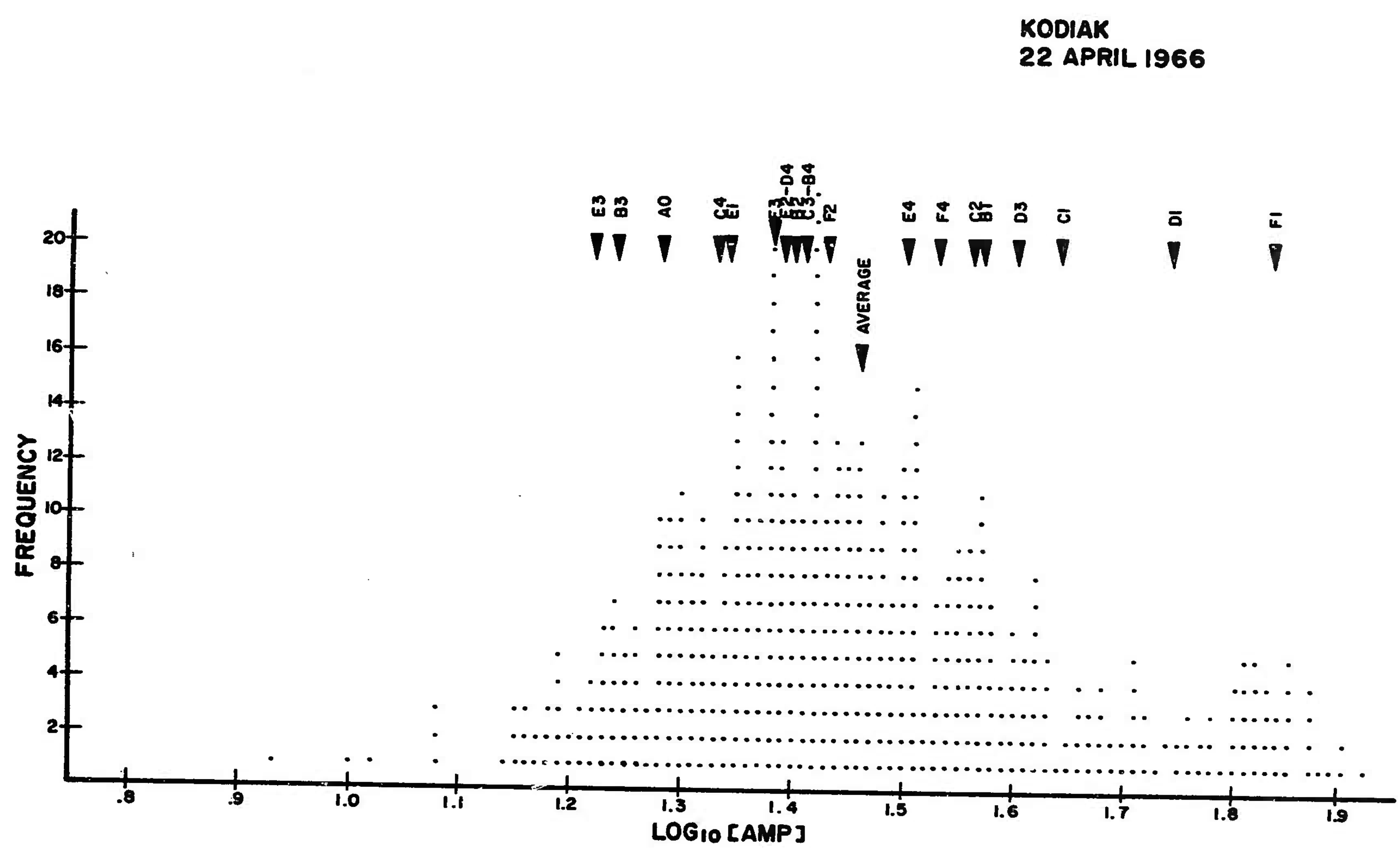

KODIAK
22 APRIL 1966
FREQUENCY
LOG10 [AMP]
AVERAGE
E3
B3
A0
C4
E1
F2
E4
F4
C2
B1
D3
C1
D1
F1

Figure 21

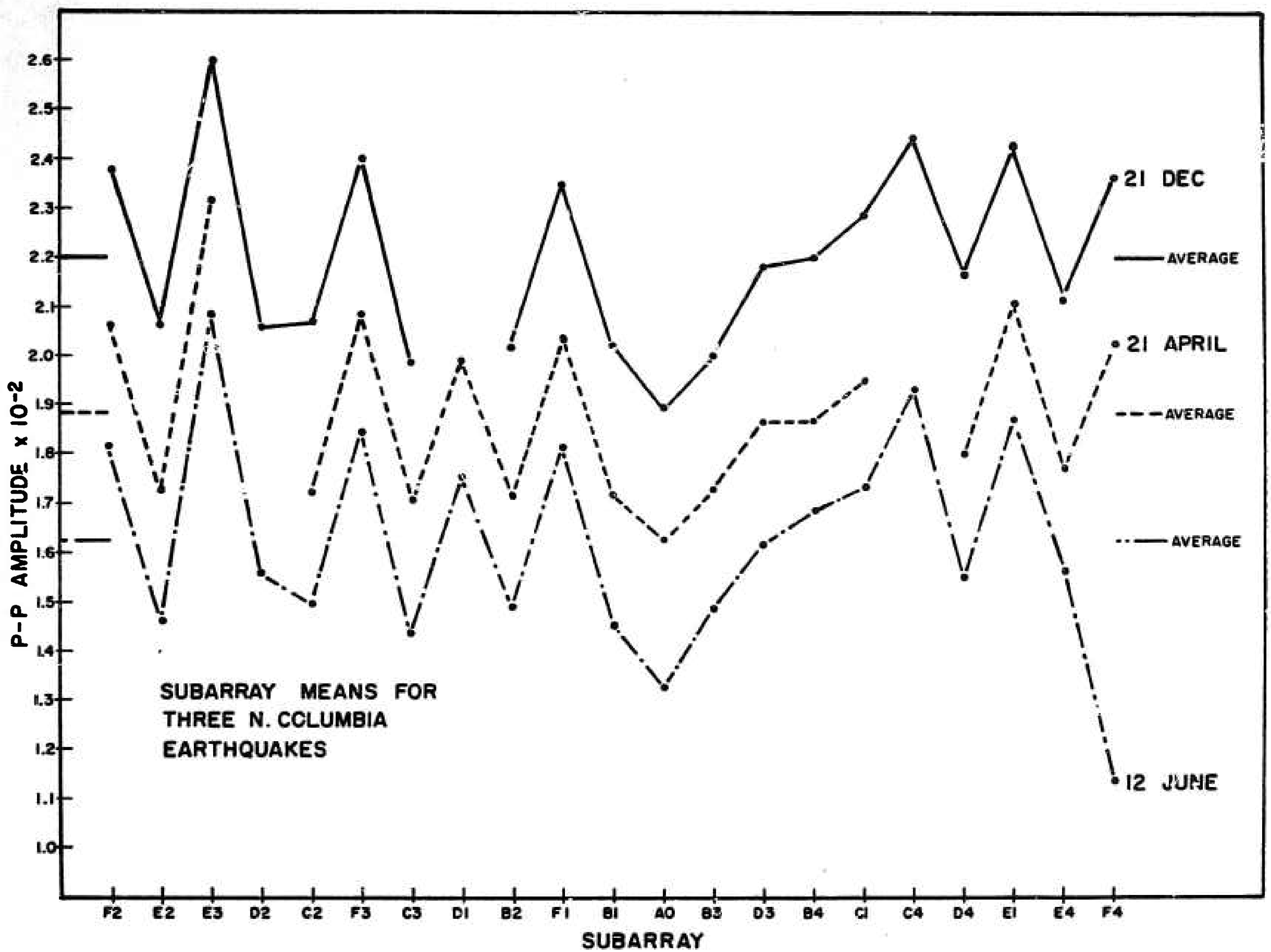
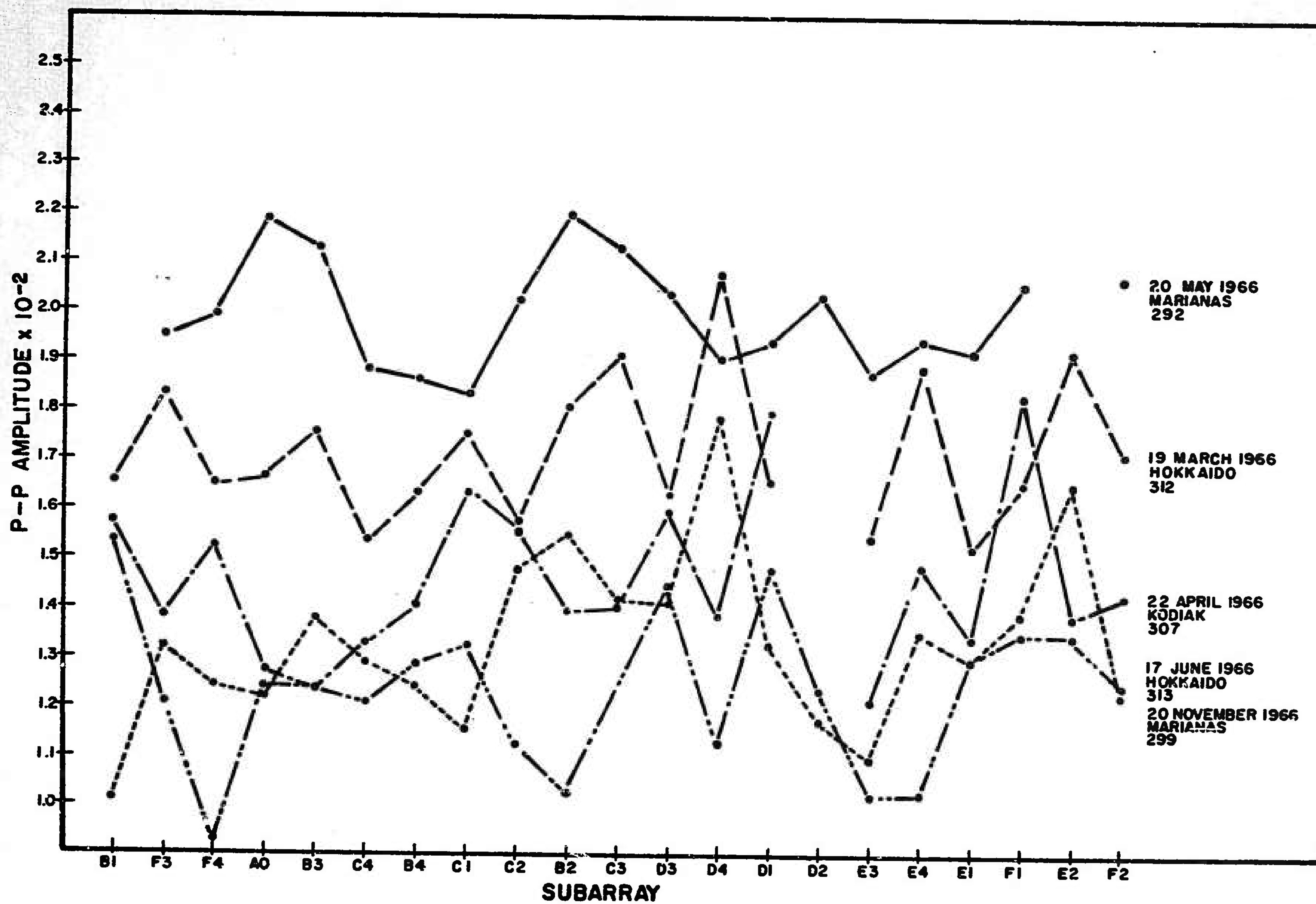

SUBARRAY MEANS FOR
THREE N. COLUMBIA
EARTHQUAKES
21 DEC
AVERAGE
21 APRIL
AVERAGE
AVERAGE
12 JUNE
P-P AMPLITUDE x 10-2
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
F2
E2
E3
D2
C2
F3
C3
D1
B2
F1
B1
A0
B3
D3
B4
C1
C4
D4
E1
E4
F4
SUBARRAY

Figure 22



P-P AMPLITUDE x 10-2
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
B1
F3
F4
A0
B3
C4
B4
C1
C2
B2
C3
D3
D4
D1
D2
E3
E4
E1
F1
E2
F2
SUBARRAY
20 MAY 1966
MARIANAS
292
19 MARCH 1966
HOKKAIDO
312
22 APRIL 1966
KODIAK
307
17 JUNE 1966
HOKKAIDO
313
20 NOVEMBER 1966
MARIANAS
299

Figure 23

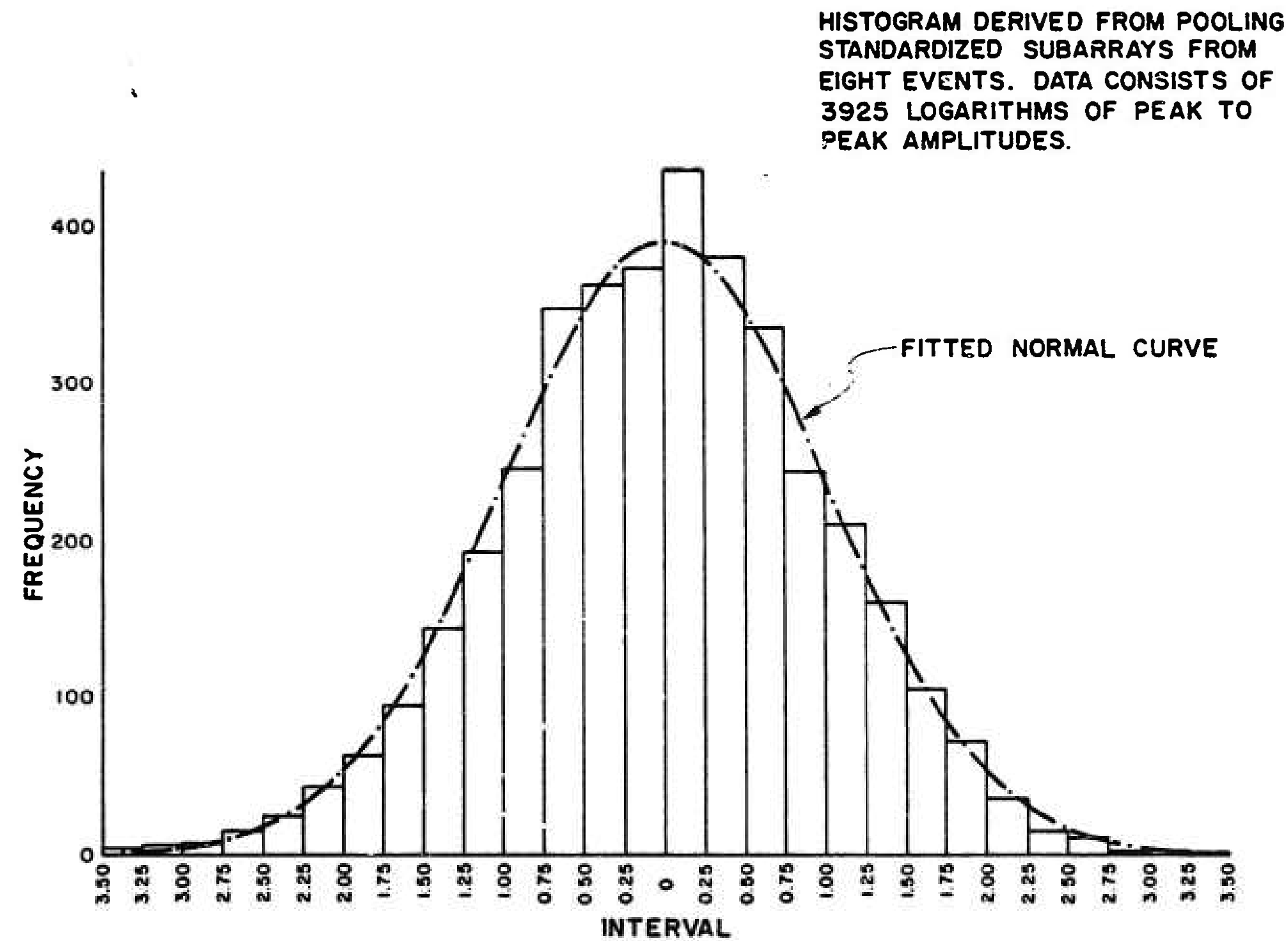

HISTOGRAM DERIVED FROM POOLING STANDARDIZED SUBARRAYS FROM EIGHT EVENTS. DATA CONSISTS OF 3925 LOGARITHMS OF PEAK TO PEAK AMPLITUDES.
FITTED NORMAL CURVE
FREQUENCY
0
100
200
300
400
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25
3.50
INTERVAL

Figure 24

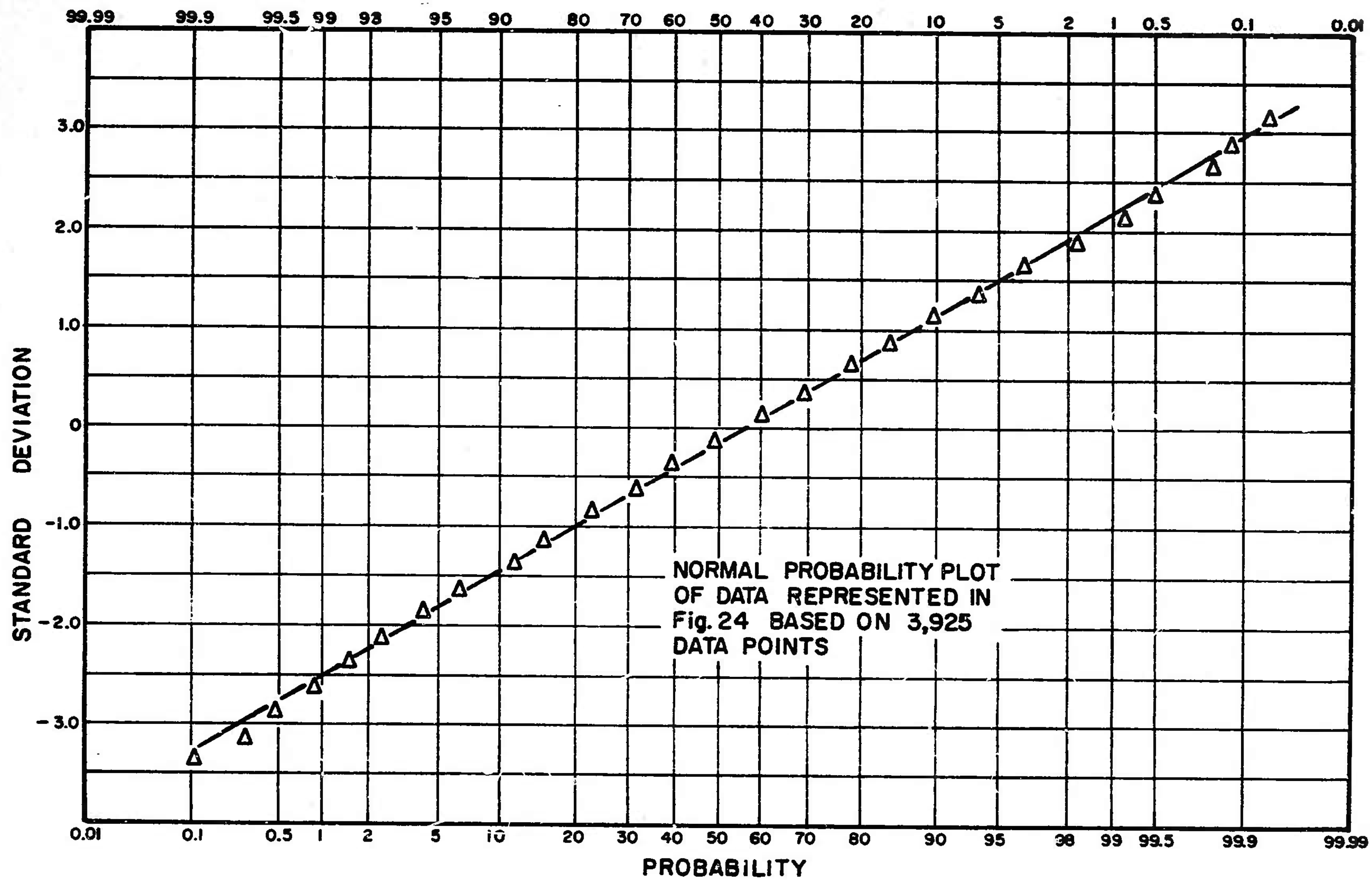

NORMAL PROBABILITY PLOT OF DATA REPRESENTED IN Fig. 24 BASED ON 3,925 DATA POINTS
STANDARD DEVIATION
PROBABILITY

Figure 25

Unclassified
Security Classification

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DISTRIBUTION OF SHORT PERIOD P-PHASE AMPLITUDES OVER LASA

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Scientific

5. AUTHOR(S) (Last name, first name, initial)

F. A. Klappenberger

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13. ABSTRACT

The behavior of short period p-phase amplitudes over LASA has been investigated for several earthquakes. It has been found that the distribution of the peak-to-peak amplitudes across a subarray approaches a log-normal distribution of those events studied.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Seismometers						
P-waves						
Distributions						

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There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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